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Editorial

TRICHOMONIASIS IN CATTLE

THE association of *Trichomonas fœtus* with abortion and sterility in cattle has been recognised in different parts of the world for some years. It was in 1937 that Stableforth, Scorgie & Gould (*Vet. Rec.*, 1937, *49*, 211) reported their findings in this country and since that time evidence has been accumulating that the presence of this protozoan parasite in the genital tract of bovines is more common than was suspected. There seems little doubt that *Trichomonas fœtus* is a pathogenic parasite and that its presence in the genital tract may be followed by death and expulsion of the fœtus in its early stage of development. In some cases no other infection appears to be present but there is also evidence that there may be accompanying infections: especially is this true in cases of pyometra. Veterinary surgeons must therefore always keep in mind, when considering causes of sterility and early abortion in a herd, the possibility of trichomoniasis and, further, the co-existence of such an infection with others which might seem more marked.

The diagnosis of trichomoniasis may not be easy. The recognition of the parasite may present considerable difficulty, especially if conditions for its preservation in a recognisable form are not good. In this number of THE

VETERINARY JOURNAL we publish an article on the agglutination reaction of the serum of cattle, infected with, and free from, the disease. One of the authors, Dr. Muriel Robertson, has just published an account of the reaction with rabbit immune sera (*J. Path. & Bact.*, 1941, *51*, 391) in which the technique of the test is described and in which it is shown that agglutinins for *Trichomonas fœtus* develop in immune rabbit sera in spite of the fact that the author failed to show that the parasite could be recovered from the blood. In the experiments described in the present article, Kerr & Robertson applied the test to cattle, and though they stress the limitations of the test as a means of diagnosis, they show clearly its usefulness in studying the course of the disease.

The article also contains an excellent account of a *Trichomonas* infection in a self-contained herd and illustrates the importance of the bull in the transmission of the disease. It also shows how animals in which "above normal" agglutination titres are present, but which were not positive to the test, are of much importance in considering infection.

This article affords a good example of collaborative effort on the part of research workers. The test had already been studied by one of them, quite apart from its likely application to the diagnosis of the infection in cattle. There was then a linking up of the two workers, both interested in trichomonads, with the result that the test was applied to cattle whose histories were well known. From this conjoint effort the value of the test in diagnosing trichomoniasis in cattle and especially in following the course of the infection in a herd has been clearly demonstrated. It has to be admitted that there are still some points which require further investigation; doubtless the authors have them in mind and we can look forward to further contributions on the subject in the future. This work is also an example of the results of close collaboration between the laboratory and the field, and emphasises fully the necessity for careful field observations and full histories of cases of disease under investigation.

General Articles

AN INVESTIGATION INTO THE INFECTION OF COWS WITH TRICHOMONAS FŒTUS BY MEANS OF THE AGGLUTINATION REACTION

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Introduction

In Northern Ireland a form of sterility unassociated with *Brucella abortus* infection is known to be the cause of considerable economic loss to the cattle industry. In certain years a series of generalised outbreaks may occur which renders this disease as serious economically as Bovine Contagious Abortion or Mastitis. (Kerr and Lamont, 1938; O'Dea, 1939.)

The system of farm management in Northern Ireland influences the incidence and etiological course of the outbreaks. Most cows are mated so as to calve in the spring, thus producing a seasonal exacerbation of the infection which is at its height in late autumn and winter. The spread of the disease is greatly assisted by the fact that 80 per cent. of the farmers own fewer than five cows and there is a communal system of bulls in operation over a large part of the province.

The clinical history shows a definite sequence of events in the average outbreak. The communal bull acquires the infection from an infected cow brought often from another district. Thereafter cows mated to this bull return service and some of them abort at about three months. The sterile cows of this group of infected animals are then mated with another bull in the hopes of obtaining better results, thus another centre of infection is set up. As many as ten small farmers may be found in each infected group.

The chief cause of this type of infective sterility in Northern Ireland has been demonstrated by direct miscroscopic evidence and by the agglutination test described in this paper to be infection with *Trichomonas fœtus*. The outbreaks may in some years reach very serious proportions and acute infections of two main types are produced; firstly, an early return of heat in three to six weeks with profuse discharge containing many trichomonas, and secondly, a uterine infection which leads to abortion usually between the second and fourth month of pregnancy. The acute phase of the outbreak, assisted by the habit of not serving the cows all the year round, sinks more or less gradually

into a latent subacute state, with many cows carrying a low degree of vaginal infection and correlated with many cases of sterility in the sense of failure to conceive. Some of these animals become obstinately sterile and are soon sold off. From this rather featureless state, in which *Trichomonas* is extremely difficult to diagnose, but which may be spread among a considerable number, the acute phase may once more be inaugurated by the gradual increase in the number and perhaps also in the virulence of the parasites and the sexual communication between bull and cow. It should be noted that the above description refers to the disease as it occurs in Northern Ireland, where severe pyometra is not generally associated with the infection. It is possible that in the disease as usually, though not invariably, seen in England and elsewhere, the acute pyometra is due to a secondary bacterial infection following upon, or coincident with, the original infestation with *Trichomonas*.

The infection of cattle with *Trichomonas fœtus* has been recognised in many countries and a very full account of the disease has been given with an excellent survey of the literature by Stableforth and Gould (1937).

The present paper deals with a study of the agglutination reaction as an added means of diagnosis and also as a method by which the course of the disease may be followed.

Witte (1934) showed that complement fixation with extract of *Trichomonas* occurred with the serum of animals which had aborted, but he considered the agglutination reaction to be unsuitable and never really explored its possibilities owing to the fact that the sera of normal cows contain agglutinins for *Tr. fœtus*. This question is taken into consideration and is discussed below.

Agglutination Test

The test used is a direct agglutination of the living washed *Trichomonas* suspended in one part of digest broth to two of Locke's fluid (mammalian Ringer's solution with glucose), or in saline. The suspension should be very thin, about 100 to a mm^3 is a very good concentration.

An account of the reaction with rabbit immune sera on which this test is based is given by Robertson (1941).

The sera are diluted in the usual way in ordinary test tubes beginning with an initial 1/3 dilution, the volume is 1.5 cc. in each tube. To this is added 1.5 cc. of the *Trichomonas* suspension so that the volume is 3 cc. and the first tube contains a final dilution of 1/6 of the serum, the titre extending in the ordinary method of dilution to 1/768 and 1/1536, etc., if desired.

As soon as the suspension is added to the serum the tubes are poured into small petri dishes (1½ inches in diameter) which have been marked with the corresponding dilution figures. These are incubated for one to two hours at 37 deg. C. and are then placed for two hours at room temperature, shaded from direct light. The first reading is made at four to five hours under the

low powers of the microscope and a second reading is made if desired at 22 to 24 hours, the plates having stood at room temperature overnight.

Owing to the fact that the test is read under the microscope and is very sensitive, and because the strain of *Trichomonas* no matter how carefully standardised varies considerably in sensitiveness, normal serum or a pooled sample of normal sera must always be included in each test and a known positive serum is also helpful.

All sera even when not of recent date must be heated to 56 deg. C. for 15 to 20 minutes. No preservative of any kind may be used in the sera. It was found advisable to use one strain, "*Tr. fœtus*—Belfast," in all these tests.

It should be clearly understood that all adult normal cattle have agglutinins in their sera (heated) for *Trichomonas fœtus*. The titre, therefore, must always be considered, when evaluating unknown sera, in the light of the normal control of the day.

A simple method of doing this by means of the conventional marking has been devised :—

The pre-agglutination zone characterised by immobilisation, the formation of small leaf-life clumps or even the absence of clumping among the many immobilised organisms, a shrinkage of the body of the organism and in some cases their death in 22 hours. *Marked with* 5 *crosses.*

Flat échelon leaf-like clumping with much reduced motility and with signs at 22 hours of the shrinkage of the bodies. *Marked with* 4½ *crosses.*

Big round clumps giving a completely clumped-up appearance with the flagella of the *Trichomonas* usually still motile. *Marked with* 4 *crosses.*

Similar clumping with, however, a few free organisms, very few in number. *Marked with* 3½ *crosses.*

Well clumped with a few free organisms. *Marked with* 3 *crosses.*

Big and smaller clumps giving a clumped appearance with a good number of free organisms. *Marked with* 2 *crosses.*

A dispersed culture with good clumps in it. *Marked with* 1 *cross.*

Small loose aggregates in good numbers and small clumps in a well dispersed culture. *Marked with* ½ *cross.*

Intermediate types between 3 and 2 and 2 and 1 are designated 2½ and 1½ crosses.

The ratio of normal to unknown and positive sera can be conveniently expressed by counting the crosses given in marking the first four plates of the series and placing the figure in the unknown over that of the known normal. This is used in all the following protocols and is called the "index."

If a test of this kind is put up with normal and "positive" sera certain differences in the reaction are observed. Table 2 gives a typical protocol with normal and positive sera. Let us first consider the normal serum. In this the organisms are found to gather into round clumps so that the posterior of the

organisms stick together and the flagella remain motile, giving a waved or fringed effect. If the suspension is very sensitive these clumps are made up of very tightly aggregated organisms, the motility of the flagella being much reduced and in the highest dilution the clumping is almost complete, giving a reading of 4+ or 3½+.

Even with a very sensitive suspension there is no trace of échelon or preagglutination in a normal serum in 1/6 and 1/12 dilutions. If échelon is found in the normal control it signifies either that the suspension is so sensitive as to be unsuitable for use, or it indicates that the normal serum has not been treated adequately so as to remove all traces of complement. In most tests with normal sera the reaction in the highest dilutions did not reach 4 crosses—3½ and 3 were more usual—the variation in the sensitiveness of the suspension might even produce 2½ as the highest figure.

The choice of the dilution figures and the number of organisms in the suspension have been made with the view of getting as sharp a line of demarcation between the average normal serum and the positive sera as possible.

In a highly positive serum the first plates show the preagglutination phase. This is of great importance and its extent marks the distinction in titre between different positive sera. Following on the preagglutination zone and of course merging into it is the échelon clumping where the organisms are found to adhere to each other by the sides of the body in thin leaf-like groups and plates one cell thick. The cells have a crushed, shrunken or dried look which is very characteristic and the flagella of the organisms are usually but not quite always immobilised. In the preagglutination phase there is every grade from single immobile or nearly immobile organisms to small flattened groups of several cells to échelon groups. The échelon group sometimes become composite, or may even be folded over by the movement of the fluid in the plate, but in the 22 hours' reaction there was never any doubt about the true échelon clumping. The échelon clumping merged into 4 or 3½ crosses.

These preagglutination (P.A.) and échelon (E.) appearances are so definite and striking that they are used as the criteria of positive sera and some clear degree of échelon clumping was made the sharp and arbitrary limit of what was designated as a positive serum reaction. In reading the tests the determination of the end point gave rise to certain difficulties which are of interest in the use of agglutination tests with protozoa and particularly with flagellates. This matter is dealt with more extensively elsewhere (Robertson, 1941) but for the present purpose it is sufficient to explain its action as manifested here.

The end point was fixed at the point at which organisms in the plates are dispersed with good numbers of solid clumps and loose rosettes—that was

where the symbol one cross was given, followed in the next plate by loose rosettes in good numbers with a few solid clumps marked (+).

The final end point where traces of rosettes can still be seen is very variable and although in very dilute serum this is still a serum reaction it depends so much on the state of the surface of the organisms that it is not of practical value in the test.

It should be remembered here that just as with bacteria all aggregation and agglutination phenomena can be brought about by non-specific means, specific agglutination by immune sera is merely one of the ways of producing this phenomenon.

The end point of agglutination in protozoa is a less valuable indication of distinction in reaction than in bacteria. It does reflect the difference, but is less reliable and is less closely connected with the apparent potency of the immune body. A good account of the reaction of the strain with any particular serum is given by stating the index figure as described above and adding the dilution in which the end-point of one cross occurs.

The degree of reaction in the higher concentrations, very clearly to be observed in a microscopic test, was found to give a good account of the distinction between the sera. It was on this account that the index was devised. The number of crosses in the first four plates was found to express the degree of the distinction, and when placed above the number in the normal control of the day, was useful in estimating the potency of the sera. The sliding scale between normals and positives with the more and less sensitive suspensions did not keep its relative ratio quite perfectly at all levels, but as the failure of the figures to respond to the variation worked slightly against the higher positives the error was not considered to be important.

Some of the points just discussed are illustrated in Table 1, which in section A shows the average index figure and the variation in the end-point— of one strain in 40 separate agglutination tests with the pool of four normal sera. This indicates the degree of variation in the sensitiveness of the strain.

Table 1, section B, shows the results of 32 normal sera in tests with one strain on separate occasions. Here the variability both of the individual suspensions and of the individual sera are expressed. Section C of this table gives the same data for 25 different positive sera. This makes it clear that the distinction between normal and positive sera is quite definite.

One more point should be noted, namely, that all protozoa, and probably bacteria too, have a tendency to release themselves from the agglutination clumps after a period of hours and the choice of the relatively low numbers of organisms was made so as to minimise this effect at the late reading. If a substantial drop in the titre was found in the second reading as compared with the first, it usually meant that the suspension contained too many organisms.

In considering this test in relation to current experience with bacterial

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agglutination the much greater amount of information as regards the behaviour of the organisms which is revealed by the microscopic observation

TABLE 1.

To show distinction in index figure and endpoint in normal and positive bovine sera. The same strain of *Tr. foetus* is used throughout.

	1/24	1/48	1/96	1/192	1/384	1/768	Average Index figure.
A. Percentage frequency of end point + in 40 agglutination tests with one pool of 4 normal sera and one strain of Tr. foetus to show the variability in sensitiveness of the strain.	10	57.5	32.5	-	-	-	3.17
B. Percentage frequency of end point + in separate tests with 32 normal sera and one strain of Tr. foetus. The variation in the sera and in the strain at different times is expressed in these figures	9.4	53.1	28.1	9.4	-	-	8.65
C. Percentage frequency of end point + in separate tests with 25 positive sera and one strain of Tr. foetus.				32	48	20	16.0

should be borne in mind. It is also important to realise that only a small and probably variable proportion of the body substance of the protozoa is antigenic. (Robertson, 1939; Kligler, Olitzki and Kligler, 1940.)

Investigation of Cattle Sera by means of the Agglutination Test

The starting point in the serological investigation was the establishment of certain cases of abortion caused by uncomplicated infections with *Tr. fœtus*. Two of these were obtained, Nos. 54 and 72, in which the *Trichomonas* were recovered from the alimentary tract of the dead fœtus and the appropriate methods for the cultivation of *Brucella abortus* and *Vib. fœtus* or other bacteria were used by Mr. Blakemore (Institute of Animal Pathology, Cambridge) without result.

The characteristic positive agglutination had been observed already in earlier cases of *Trichomonas* abortion in Northern Ireland, but in these the exclusion of other possible causes of abortion were not so perfect. These sera were used as types of positive reactions. Another means of obtaining positive sera of indisputable authenticity was adopted. Three virgin heifers were vaccinated at Stormont, Belfast, by the injection of washed *Trichomonas*. In the first case the organisms were injected intravenously, which proved to be rather a dangerous proceeding owing to the seriousness of the reaction in the later stages of vaccination. The other two animals were successfully inoculated intramuscularly. The animals produced high-power sera, giving a reaction with *Trichomonas fœtus* as potent and finally more potent than that obtained from the serum of recently aborted cows.

With these positive sera and a normal serum pool obtained from Mr. Rider's small self-contained herd near Darlington with a long recorded history of regular normal births as standards, the sera of a large group of cases were investigated. A Cambridge pool of young pregnant heifers was also used at times.

Mr. Hignett kindly supplied the sera of three young animals which had been infected with *Corynebacterium pyogenes* and subsequently injected with toxoid of the same organism. This treatment caused no rise in the titre against *Trichomonas fœtus*. Advantage was also taken of some immunisation experiments with *Br. abortus* being carried out by Dr. Paterson on a number of young virgin heifers at the Institute of Animal Pathology, Cambridge, to get high titre abortus immune sera with perfectly certain exclusion of any *Trichomonas* infection latent or declared.

As will be seen in Table 3, a high titre against *Br. abortus* did not alter the normal agglutinin titre against *Tr. fœtus*.

The reactions in normal and positive sera have already been described but there was a puzzling group where the titre fell in between the two. That is to say there was no échelon clumping and they were therefore not classed as positive, but the degree of agglutination was nevertheless definitely greater and the index figure higher than in the normal. The significance of the "above normals" is considered below in a later section.

TABLE 2.

To show reaction of *Tr. fœtus* with positive sera from aborted cow and the gradual loss of titre with passage of time; sera from artificially vaccinated virgin heifer and normal controls are included.

Sera.	1/6	1/12	1/24	1/48	1/96	1/192	1/384	1/768	1/1536	1/3072	Saline Control.	Index	No. of Test.
Ser.72 (1) 17 days after abortion.	P.A. ++++	P.A. +++++	E ++++(+)	E ++++(+)	++++	+++	++(+)	+(+)	+	(+)	-	19	321
Ser.69 Normal control.	+++	++(+)	++	+(+)	+	(+)					-	9	317
Ser.72 (3) 5½ mths.after ab.	+++(+)	+++(+)	+++	++(+)	+	+	(+)				-	13½	564
Ser.72 (4) 8½ mths.after ab.	Tr.of E ++++	+++(+)	+++	++	+(+)	+	(+)				-	12½	565
Ser.72 (5) 13 mths.after ab.	++++	++(+)	++(+)	++	+(+)	+	(+)				-	12	566
N.A. (14) Artificially immunised virgin heifer.	P.A. +++++	P.A. +++++	E &P.A. ++++(+)	E ++++(+)	E ++++(+)	+++(+)	+++	+(+)	+		-	19	568
Rider's Normal Pool (2)	+++	++	+(+)	+	(+)						-	7½	569

P.A. = preagglutination zone.
E. = flat echelon clumping.

This protocol shows tests with sera derived from an animal aborting with an uncomplicated *Trichomonas fœtus* infection.

Tests 321 and 317 illustrate the results at 17 days after abortion and with the normal control of the day the index is 19/9. The serum is a high positive.

Tests 564, 565 and 566 show the drop in the titre with the passage of time. In 564 the index is $13\frac{1}{2}/7\frac{1}{2}$ with echelon clumping in 1/6 it was registered as a low positive.

In test 565 there was only a trace of E in 1/6 and with the index $12\frac{1}{2}/7\frac{1}{2}$ it was considered to be a border line titre and was classed as definitely "above normal" but not a positive.

In test 566 where the serum was taken 13 months after the abortion there was no E clumping and with the index of $12/7\frac{1}{2}$ it was classed as a good "above normal."

Test 568 shows the result of the same day with serum N.A.(14) from a virgin heifer vaccinated artificially by the intramuscular injection of *Tr. fœtus*. This was a high positive, the index being $19/7\frac{1}{2}$.

TABLE 3.

To show reaction of *Tr. fœtus* with a postive serum several "above normals," the positive *Brucella abortus* pool and the sera of the normal controls.

Sera.	1/6	1/12	1/24	1/48	1/96	1/192	1/384	1/768	1/1536	1/3072	Saline Control.	Index.	No. of Test.
N.A. (12) heifer.	P.A. +++++	PA.& E. ++++(+)	E ++++(+)	++++	+++	++(+)	+(+)	+			-	18½	515
126. "Returns" after 6 weeks.	++++	+++	++(+)	+(+)	+	(+)						11	516
135. 3 months after abortion.	++++	+++(+)	++(+)	+(+)	+	(+)						11½	517
136. Roan Bull.	++++	+++(+)	+++	++(+)	+(+)	+	(+)					13	518
137. Black Bull.	++++	+++(+)	+++	++(+)	+(+)	+	(+)					13	519
Rider's Pool(2) Normal.	++(+)	++	+(+)	+	(+)							7	520
4 & 5 (3) Virgin heifer.	+++	+++	+(+)	+	(+)							7½	579
Abortus Pool Sample (2)	+++(+)	++	+(+)	+	(+)							8	580
Rider's Pool of Normal Cows (2)	+++	++(+)	+(+)	+	(+)							8	581

P.A. = preagglutination zone.
E. = flat echelon clumping.

Serum N.A. (12) (test 515) from vaccinated heifer, index $18\frac{1}{2}/7$ = positive.

Serum 126 (test 516) is from an animal which came again into season after six weeks, index $11/7$ = "above normal."

Serum 135 (test 517) is from a herd where there had been cases of abortion with mummified calves. This cow had aborted 3 months previously. Index $11\frac{1}{2}/7$ = "above normal."

Sera 136 and 137 (tests 518 and 519) are from Irish bulls which were considered to have infected this herd. Index 13/7 in both cases which is definitely "above normal" but they are not true positives. No. E clumping.

Abortus Pool 2 (test 580) this was the pooled serum of 7 animals, virgin heifers vaccinated with *Br. abortus* titre 1/160—1/640.

Rider's Pool 2 (test 581) is the pooled serum of four normal cows.

TABLE 4.

Typical experiment. To show reaction with different types of cow sera.

Sera.	1/6	1/12	1/24	1/48	1/96	1/192	1/384	1/768	1/1536	1/3072	Saline Control	Index.	No. of Test.
Ser.149.	++++	+++(+)	++	+(+)	+	(+)	(+)				-	11	558
113 (2) 4 months after abortion.	E &PA. ++++(+)	Tr.E. ++++	++++	+++	++	+	(+)				-	15½	559
37 (3)	++++	+++(+)	++(+)	+(+)	+	(+)					-	11½	560
75 (1) 3 days after abortion.	PA.& E. ++++(+)	E. +++(+)	E. ++++(+)	E. ++++(+)	+++(+)	+++	+(+)	(+)			-	18	561
75 (2) 6½ months after abortion.	E. ++++(+)	E. ++++(+)	+++	++	+(+)	+	(+)				-	14	562
Rider's Pool (2).	+++(+)	++(+)	++	+(+)	(+)						-	9½	563

P.A. = preagglutination zone.
E. = flat echelon clumping.

Serum 149 (test 558), this is from a cow after calving quite regularly has begun to show "sterility" returning into season 3 times in 3 months. Service was by infected bull. Index $11/9\frac{1}{2}$ = not significantly above normal.

Serum 113 (test 559) four months after abortion from the same infected herd. Index $15\frac{1}{2}/9\frac{1}{2}$ = good positive.

Serum 37 (test 560) from animal showing irregular sterility; from same infected herd index $11\frac{1}{2}/9\frac{1}{2}$ = above normal but not significantly.

Serum 75(1) (test 651) 3 days after abortion. Large number of trichomonas in placental fluid; index $18/9\frac{1}{2}$ = good positive.

Serum 75(2) (test 562) same animal as foregoing 6½ months after abortion; index $14/9\frac{1}{2}$ E clumping still present = positive but titre has begun to drop.

Control is Rider's pool of normal cows.

TABLE 5.

Showing reaction of *Tr. fœtus* with sera from animals in an infected herd where detailed histories were lacking. No. 101 had aborted 2 months before the sample was taken. Rider's pool 2 and the serum of a young virgin heifer are included.

Sera.	1/6	1/12	1/24	1/48	1/96	1/192	1/384	1/768	1/1536	1/3072	Saline Control	Index.	No. of Test.
101. 2 months after abortion.	PA.& E. +++++	E. ++++(+)	+++(+)	++(+)	+(+)	+	(+)				-	15½	570
Serum 134	E.& Tr.PA. ++++(+)	Tr.of& ++++	+++(+)	++(+)	+(+)	(+)						14½	573
130	++(+)	+++	++	+(+)	+							10	571
131	+++(+)	+++	++	+(+)	(+)							10	572
A 7 (2) Normal heifer.	+++(+)	+++	+(+)	+	(+)							9	574
Rider's Pool (2)	+++(+)	++(+)	+(+)	+	(+)							8½	575

P.A. = preagglutination zone.
E. = flat echelon clumping.

Serum 101 (test 570) is positive as is also 134 (test 573) though the titre is slightly lower. Sera 130 and 131 with index of $10/8\frac{1}{2}$ and no E clumping are about the normal level and so is A7(2) the virgin heifer.

The tables (Nos. 2—5) are examples of typical tests with sera from a variety of sources.

Result of Survey of 165 Animals examined by means of the Agglutination Test

The total number of animals reviewed in this set was 165. They were divided into three groups: (1) Forty-five animals with completely normal histories; (2) twenty-five cows and heifers with histories of abortion or sterility with a definitely positive blood reaction; and (3) ninety-five animals with some history of sterility or abortion either in their own or in that of the other members of the herd. This group included some animals with a known infection with *Corynebacterium pyogenes* and with *Brucella abortus*.

If the definitely positive group (2) and group (3) which was made up of animals with suspicious histories or their fellows in the same herd are taken together they make a set of 120 animals. Table 6 shows how they were arranged according to the results of the serum test.

Out of twenty-five positives, *Trichomonas* was seen by a competent observer in nine cases and also in one animal whose serum was "above normal." The distribution of abortion is given in Table 6 but this set of figures has not very much significance, as the group was too heterogeneous and the histories of abortion given by farmers are often so obscure as to have little scientific value.

TABLE 6

Results of serum test in Group (2) *and Group* (3)

Total No. tested.	Animals with *normal* blood titre.	Animals with titre *above normal.*	Animals with *positive* blood titre.
120	55	40	25
Distribution of obvious "abortion"	9 = 16.3%	11 = 27.5%	13 = 52%

Certain important things were brought to light during this survey. In the first place a positive blood titre for *Trichomonas* was not found in any of the animals with perfectly normal histories nor in virgin heifers. Animals infected with *Corynebacterium* and *Br. abortus* reactors as already stated did not show a raised titre for *Trichomonas fœtus*.

There was a clear connection between the positive blood titre and uncomplicated infection with *Tr. fœtus* in a number of cases. The converse, however, was definitely not established, namely, that absence of the positive titre implied absence of any degree of infection. In fact it was demonstrated in one (151) of the series quoted above that an animal may harbour *Trichomonas* in the vaginal secretion with no significant rise in the serum agglutinins in the blood.

Abortion was associated with the positive blood titre in 13 of the 25 cases,

i.e., in 52 per cent. This is a high percentage and does not include two cases where a positive blood reaction was obtained from the sera of two animals who showed return of œstrus at six weeks with numerous *Trichomonas* in the discharge. These were not classed as obvious "abortions" in the sense used by the farmers and are not included under that heading.

The acquiring of the raised blood titre needs further study and is at present under investigation. So far there is good evidence of its presence immediately after the abortion and one case (No. 75) showed it in a sample taken on the third day, but it may have been present earlier. It has also been found in the serum of two animals (No. 13 and No. 29) consequent upon a return of œstrus at six weeks accompanied by a vaginal discharge heavily infected with *Trichomonas fœtus*.

Discussion

In considering the value of the agglutination test for *Trichomonas fœtus* it is important first of all to be quite clear what it is that this test is concerned with. It is purely a measure of the rise in the agglutination titre of the blood for *Trichomonas*. As already stated, it is not a test of the presence of *Trichomonas* infection.

The infection with *Tr. fœtus* is apparently a true venereal disease and the actual sojourn of the organism, unlike that of *Br. abortus*, which can be found in many different sites, is in the genital tract. The present writers have not been able in spite of many attempts to confirm Wagner and Hees's (1936/37) contention that *Tr. fœtus* takes up its abode in the blood.

The connection of the rise in titre of the antibody with the more acute phase of the disease has been demonstrated here and also in Witte's work on complement fixation (1934) though the mechanism by which this raised titre is acquired is not yet clear.

The "above normals" have been shown to occur certainly as examples of the falling titre of animals which have been acutely infected at one time, but so far an "above normal" has not been definitely demonstrated in an incipient infection, though this matter is being studied.

The obvious value of the test lies in the light it throws on the state of infection in groups of animals and in tracing the course of the disease. It is a valuable adjuvant to the direct examination which very often yields negative results even in definitely infected animals. The difficulty in demonstrating *Trichomonas* and the great variation in the numbers present are notorious.

It may be noted that 25 cases were diagnosed by the agglutination test, whereas only in 10 instances were *Trichomonas* observed by direct examination. The cases were all in the hands of experienced veterinary practitioners, all of them aware of the possibility of *Trichomonas* infection and some of them specifically on the look out for it.

The agglutination test is probably more sensitive and certainly much

simpler to carry out than the complement fixation test used by Witte (1934). The present authors do not in any way consider that the blood test can supersede direct examination, nor do they wish to claim for it more than its value as a means of detecting certain types of cases.

In practice it may be considered that if one animal with a definitely positive serum reaction is found in a herd it is an indication of a serious *Trichomonas* infection whether the organism can be found or not.

Sterility and abortion manifest or inferred from the return of the œstrus cycle should be reviewed from the standpoint of this infection and the appropriate treatment should be carried out with the subsequent isolation of the treated and healthy animals from the infected bull.

In this investigation in the field once animals whose sera showed positive reactions were found the infecting bull could nearly always be traced and the further spread of the disease could be followed up.

An account of a *Trichomonas* infection which occurred in a self-contained herd with carefully kept records is given below, as it affords a valuable illustration of some of the questions dealt with in this paper.

Summary

(1) The application of the agglutination reaction in the study of the sera of cows infected with *Trichomonas fœtus* is described.

(2) A study of the normal level of the agglutinins in cattle sera for *Tr. fœtus* is made and the distinction in the titre and in the kind of agglutination which is connected with certain types of *Trichomonas* infection is emphasised.

(3) Sera with a high agglutination titre against *Br. abortus* and also that from animals which had been infected with *Corynebacterium pyogenes* and then injected with the toxoid showed no increase in the normal titre against *Tr. fœtus.*

(4) The sera of 120 animals with histories of sterility and/or abortion were examined for their agglutinins against *Tr. fœtus,* 25 animals showed a definitely raised titre, i.e., gave a positive reaction with living *Tr. fœtus.*

(5) The connection of the raised titre and the disease was established in certain cases where the organism was present in the aborted fœtus and no other cause of abortion could be detected by cultural methods. The positive titre was also present in certain cases of early return of œstrus at six weeks accompanied by a discharge in which there were numerous *Trichomonas.*

(6) The duration of the raised titre in the sera of aborted animals is variable but may last several months. Both the acquiring and the loss of the enhanced agglutination titre requires further study.

(7) The limitations of the test as a means of diagnosis are stressed while its usefulness as a method of studying the course of the disease are pointed out.

(8) A positive reaction has been associated with *Trichomonas* abortion

and has never been found in the sera of animals with perfectly normal histories.

(9) The "positive" titre appears at present to be solely connected with animals which are or have been infected with *Tr. fœtus*. The converse, however, is not true. A normal titre for *Trichomonas* in the serum of animals does not imply that they are therefore free from infection with *Trichomonas fœtus*.

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ACCOUNT OF A TRICHOMONAS INFECTION IN A SELF-CONTAINED HERD

About 1934/35 there was a well-authenticated outbreak of *Trichomonas* infection in a herd with carefully-kept records. This was to all appearance successfully eradicated.

In 1940/41 it reappeared. The history of this outbreak throws an interesting light on the ætiology of the disease.

It is stated that service was never given to cows outside the herd and no bulls were bought that had ever been used before purchase. A few cows were, however, bought. The herd was free from infection with *Brucella abortus*.

The first indication of anything being wrong with the herd was failure to conceive on the part of certain animals which had previously had excellent records, followed by the clinical symptoms of excessive vaginal secretion, i.e., "discharge." There was, however, no direct evidence of *Trichomonas*. These symptoms were sufficiently serious in January, 1940, for notice to be taken of them. The animals had "above normal" blood titres but were not positive to *Trichomonas* and had they stood alone would not have yielded a characteristic diagnosis (cow Nos. 35, 36 and 37).

The first abortion (cow No. 54) occurred in February, 1940, and this was clearly caused by *Trichomonas*. The abortion took place at 4½ months and is actually the latest *Trichomonas* case of the whole series. *Trichomonas* was found in the stomach of the calf and was cultivated; the blood reaction of the cow was positive.

This was followed in the next ten months by four further abortions, all of which showed the characteristic blood reaction and *Trichomonas* was obtained from the only fœtus which was sent in for examination.

In looking into the histories there seems to have been at least one link

between the 1934 and the 1940 outbreaks in so far as bull "B" seems to have been used with some of the cows of the first series. This origin for the second outbreak seems the more probable, as the disease did not apparently start up in an immediately acute form in 1939/40.

There were three bulls being used over the important period of 1938 to 1940. Firstly, bull "A," an old bull just finishing his breeding career, which had an excellent record of successful services and of calves being born to time. Secondly, bull "B," an animal which after a good start entered into many of the early histories of cows which later aborted or were sterile. He had a record of many failures and of repeated services in 1939 but was not incriminated apparently in any acute cases. Thirdly, the bull "C," which finally was passing on the acute infection but which had frequently been used after unsuccessful services by "B."

The bull "C" was born on this farm in 1936 and had an excellent start, producing calves to time with the first services in 1938 and the early part of 1939. In 1939, somewhere about September, he was clearly infected and all five *Trichomonas* abortions were from his services.

The career of bull "C" is instructive, as after his first "good period" the only remarkable circumstances in the inception of his "bad period" was that the cows and heifers served by him failed to conceive or "returned service," but were for the most part finally got into calf by his service. This marks apparently the period of feeble latent infection in a rising outbreak (Nos. 36, 37 and 113). An excellent example of this is cow No. 113 which had her first calf in 1938 by service of bull "B" and her second calf to time by service of bull "C," but in July to October, 1939, she was served four times by "C" before finally being put in calf by service on October 12, 1940. "C" was certainly infected at this period and it is probable that the frequent return of œstrus in this cow was connected with the infection of the bull. She calved to time in July, 1940. On August 30, 1940, this cow was served by "C" and aborted at 3½ months with a positive blood titre for *Tr. fœtus.*

"C" became infected between June and September, 1939, as shown by his history at and after this last date. Thus, on September 12, 1939, he served cow No. 54, which aborted with *Trichomonas* demonstrated in the fœtus and positive blood titre at 4½ months.

On December 16, 1939, he served cow No. 72, which aborted at 3½ months again with *Trichomonas* demonstrated in the fœtus and with a positive blood titre. On that same day, December 16, cow No. 82 was served and aborted at three months; the fœtus, however, was not brought for examination but the blood of the cow still showed a positive titre three months later.

There were subsequently the two more abortions already noted with positive blood titres for *Trichomonas* and a good deal of sterility and difficulty in getting animals into calf, but it must be carefully noted that an infected

bull can still have some successful services and infected cows can also in some instances produce full-time calves at a later pregnancy.

Thus, cow No. 82 finally was put into calf to "C" 2½ months after the abortion, cow No. 87 was also got into calf this time at the first or second service. But several animals, notably Nos. 54, 72 and 35, were rendered useless as breeding animals and were sold fat.

Intra-uterine irrigation with iodine was not used to treat the cows on this farm in the 1940 outbreak, although douching of the vagina with Chinosol was resorted to as a routine procedure. This outbreak was not characterised by the production of pyometra.

The tendency to consider an untreated (or inadequately) treated cow as "cured" because she can finally be put in calf after a *Trichomonas* infection is obviously a fruitful means of spreading the disease.

It must also be noted that all abortions as such or failures to conceive in an affected herd must not be attributed to infection with *Trichomonas* without further investigation. Anœstrus from other causes, persistent corpus luteum, infection with *Brucella abortus*, etc., can occur in a herd infected with *Trichomonas* as in any other.

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A CONTRIBUTION TO THE STUDY OF SOME ETIOLOGICAL FACTORS CONCERNED IN THE PATHOGENESIS OF DISEASES OF DOMESTIC ANIMALS

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In the investigation of the etiology of the various diseases of animals it becomes apparent that a number of factors, some known and some unknown, play a part, and that in most cases it is very difficult to set up experimentally, by bringing into operation the known factors concerned under conditions such as could obtain under natural circumstances, a disease condition identical in all respects with the naturally occurring one and, if success in this should be obtained, it often happens that attempts to repeat this result, employing apparently the same factors, meet with failure. There appears to be no room for doubt that the genetic constitution, the influence of previous environment, the influence of present environment, the dose, route of administration and virulence of the "infective agent," using this term to include protozoa, bacteria, viruses and other foreign protein, all play a part in determining whether or not an animal will become affected with the disease under investigation.

In this paper it is intended to survey literature instancing the influence of the present environment or, rather, of those factors within that environment which have been recorded to have so lowered the resistance of animals under the conditions which operated at a particular interval of time in their life, that overt manifestations of disease became evident apparently as a direct sequel.

Influence of Exercise

Rose (1934) found that, while sometimes exercise succeeds in cutting down the incidence of entero-toxæmia in sheep, often the moving about of sheep only accentuates the mortality rate. On one property, where losses were occurring at the rate of one or two weekly, fifteen or twenty lambs died during the day and a half that they were travelling a couple of miles with their mothers to be shorn. He also relates that one of the heaviest losers from entero-toxæmia specifically mentioned that handling the sheep and knocking them about to any extent was always followed by an increase in the death rate.

Smith (1897) found that exertion, even moderate, will give rise to pneumonia in a young horse which is out of condition. He says he has given young horses pneumonia through simply testing them for their wind.

Male (1919) states that, if a horse is worked while suffering from a high temperature occurring during an attack of influenza, pneumonia nearly always resulted.

Kennedy (1906) writes that his manager observed that the less sheep stock was hustled so much the less was the loss from louping ill.

It is well known that an attack of azoturia in the horse is usually precipitated by exercise following a period of idleness accompanied by high feeding (Hoare, 1915).

Influence of Transport and Travelling

Woodruff (1910) found that travelling by train or, to a greater degree, by ship adds to the danger of young horses contracting pneumonia.

Anon. (1920) showed that, in animals being shipped to Alexandria during the Great War, those which were embarked immediately after a long train journey in the winter months suffered more severely from pneumonia than did those which were allowed to rest a few days before shipment.

Hutyra *et al.* (1938, Vol. I, p. 140) state that fatiguing transport by rail, motor or ship, especially in cold, damp weather in the spring and autumn, often leads to outbreaks of Pasteurellosis in sheep.

Mongomerie *et al.* (1938) find that enzootic pneumonia of sheep may be induced by travelling on foot or in trucks.

Hepburn (1925) and Anderson (1939) describe the catarrhal condition known as Transit Fever, which occurs principally in cattle shipped from Ireland or Orkney or in cattle transported by rail during the cold months of the year.

Hutyra *et al.* (1938, Vol. I, p. 109) state that outbreaks of fowl cholera may occur after carrier fowls have been exposed to prolonged transport in crowded wagons and in bad weather.

Ibid. (p. 124) make mention of the adverse effects of cold and fatigue in transport on the incidence of Pasteurellosis in rabbits.

Ibid. (p. 9) state that anthrax sometimes develops, especially in carrier cattle in summer, four to five days after prolonged road or rail transport.

Queripel (1878) records outbreaks of anthrax in sheep which appeared to be precipitated by the fatigue of a journey.

Whitworth (1926) states that it has frequently been reported and observed that animals after a train journey or a sea voyage suddenly die of anthrax, probably indicating breakdowns in carrier animals.

Anthony (1931) is led to believe that swine erysipelas may be precipitated in carrier pigs by a railway journey.

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Hutyra *et al.* (1938, Vol. I, p. 81) state that fatigue, especially during transport, leads to the frequent appearance of swine erysipelas in pigs which are carriers of the bacillus.

Daubney (1926) records that heavy losses from paratyphoid infection occur in lambs while they are being trekked from the more southerly states to the northern pastures.

Montgomerie *et al.* (1929) and Green *et al.* (1935) record cases of tetany in Welsh mountain ponies which have been rounded up on their mountain or moorland grazing and taken a considerable distance by rail.

Blumer *et al.* (1939) record that, following the winter rains in June and July, 1938, which resulted in lush grazing conditions over a large area in New South Wales, a considerable number of cases of "grass tetany" occurred among pregnant and lactating ewes. Out of 16 recorded outbreaks investigated 75 per cent. were apparently due to, or were precipitated by, droving. In one instance about 600 pregnant ewes were grazing on a young wheat crop. A portion of the flock was sold and put on the road. After travelling a few hours the first case developed. By the end of the first day 40 cases had occurred. No cases developed in the unsold portion left grazing. In another outbreak, out of 750 ewes with lambs at foot 150 became affected a short time after they started travelling to the shearing shed.

Hunting (1902) says a railway journey has been known to render prominent all the symptoms of shivering in a horse which before the journey was not known by its owner to suffer from any unsoundness.

Shipley (1902) tells of a horse he had examined and passed sound. The animal was sent 40 miles by rail and directly it got off the train it showed marked symptoms of shivering.

Kitchen (1902) states that he had seen many horses that came off a railway journey apparently all right, but had been found next day to be shiverers.

McCall (1910) states that cases of shivering have been known to develop following a railway journey.

Coe (1902) attributes cases of laminitis in horses to be associated with journeying long distances by rail and also with being shipped.

Influence of Frights, Accidents and Operations

Smith (1902) describes how a horse, previously apparently unaffected with shivering, showed symptoms of this disease after being pulled out of a dyke into which it had accidentally fallen; it remained a shiverer.

McCall (1910) says that a sudden fright or shock may produce marked symptoms of shivering in a horse which hitherto appeared free from the affection. He also has known street accidents to cause development of latent

cases of the disease. Docking of the tail of a horse has been credited with having a similar effect.

McCunn (1937) records a case of tetany in a dog, the onset of which coincided with a great fright the dog had when savaged by a much larger animal.

Gill (1934) considers that fright, heat and pain from collecting, yarding and "marking" may precipitate cases of entero-toxæmia in lambs which are at the "critical metabolic stage" of their life, and on the morning following the operation of these factors several of these lambs may be found dead of entero-toxæmia.

Influence of Cold and Wet

Lawson (1870) considers that cold and wet are frequent causes of grease in horses.

Hornby (1920) describes a contagious impetigo of cattle which occurs during the rainy season when the conditions of moisture and warmth, necessary for the growth of the associated fungus, are present.

Davis (1900) attributes gangrenous dermatitis of the coronet and pastern of horses to exposure to intense cold. He also describes cases of a virulent form of "mud fever" occurring in horses working knee-deep in mud in coal mines.

Manuel (1890) records an outbreak of disease in sheep which were netted in a field with very little shelter during a period of almost constant rain accompanied by high winds. The field was very muddy. The sheep suffered from an eruption on the skin of the nose followed in a day or two by a discharge from the nose of blood and mucus.

Slagsvold (1935) describes a condition, occurring especially in the comparatively rainy westerns districts of Norway, in which parts of the skin of sheep and goats become infected with a fungus. Neglected care of the skin, together with cold and dampness, favours the development of the disease.

Davis (1928) states that in New Zealand cases of pleurisy in sheep are attributed to the influence of wet pastures.

Montgomerie *et al.* (1938) record an extensive outbreak of enzootic pneumonia in sheep which followed a short heat wave in early May, 1935, succeeded by a period of cold east winds.

Mitchell (1915) relates that Jaggziekte or chronic catarrhal pneumonia of sheep causes greatest mortality in particularly wet years and that more cases occur during the rainy season than during the dry season.

Allen (1929, b) records that at Mona Remount Depot, Punjab, cases of equine pleuro-pneumonia occur, whereas it has never occurred at a sister depot 40 miles distant. The former is heavily wooded in parts, the land on the whole is low lying, some paddocks are not well drained, heavy clayey soil in parts,

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and there is a tendency to water-logging; the latter is situated on undulating well-drained land and is not heavily wooded nor do water-logging conditions exist. The disease appears seasonally and may be governed by the great variations of day and night temperatures.

Smith (1897) considers that cold and wet can be causative factors in the development of pneumonia in horses.

Woodruff (1910) finds that pneumonia in horses is much commoner in winter than in summer; it is especially likely to be met with after a sudden severe fall of temperature, especially if accompanied by wet weather.

Mayall (1935) finds that in cows the commonest cause of pneumonia he meets with is the coming out of a warm shippon into cold and icy blasts.

Greaves (1891) records an influenza epizootic in horses occurring during intensely cold, foggy weather.

Male (1919) states that, in his experience, nearly all bad outbreaks of equine influenza have occurred during a long spell of severe weather, either cold or continuously wet.

Griffiths (1924) describes a seasonal gastro-enteritis in cattle in Nyasaland, which is associated with abundance of succulent herbage and occurs during the rains. A burst of heavy rain with cold nights or a long journey in the rains may give rise to a crop of cases.

Masheter (1931) describes cases of sudden fatal illness in two rapidly thriving calves which were housed in a barn situated in a very exposed situation. A post-mortem examination of one of them revealed lesions similar to "pulpy kidney" in lambs. At the time of the deaths, which both occurred within two days of each other, there was a strong, very cold, easterly wind which blew through the barn without much hindrance.

Penhale (1900) found that blackquarter was most prevalent about the month of October during a period of heavy rainfall.

Brownlee (1940) refers to literature on the well-recognised influence of hoar frost on the incidence of braxy in sheep.

From the Report to the Louping Ill Committee, Teviotdale Farmers Club (1881), the general consensus of opinion among farmers and shepherds seemed to be that cold easterly winds led to an increase in the incidence of louping ill in sheep.

Percival (1850) writes that, it is said, he believes on sufficient authority, drinking a large quantity of cold water by horses while heated has been followed by laminitis.

Thomson (1900) states that laminitis in horses occurs after the animal has had an overdraught of cold water or has stood too long in a cold draught after being heated or after travelling amongst snow.

Greig (1936) states that numerous outbreaks of abortion in ewes in

Scotland were definitely associated with folding ewes on turnips, especially during cold, wet weather.

Jackson (1910) refers to a statement by Mr. Franklin, Stevenage, that on certain farms in his district, where swine erysipelas is persistent, it is recognised that, if the dung be removed from under fat pigs, letting them down on the unpaved floor, an outbreak of swine erysipelas is likely to follow.

Influence of Loss of Protective Coverings

Lawson (1870) considers that continual trimming of the hair of the heels of horses is an exciting cause of cracked heels and grease.

Broad (1873) and Freer (1896) consider that clipping of the hair of the legs of horses is a predisposing cause of "mud fever."

Dodd (1916) states that large numbers of sheep pasturing on trefoil may be affected with a photosensitisation dermatitis of the skin of the back as a result of the protective covering of the wool being removed at shearing.

Bull and Macindoe (1926) also describe a photosensitisation dermatitis of the back of sheep occurring after shearing. The sheep had been grazing on pasture containing trefoil.

Hutyra *et al.* (1938, Vol. I, p. 123) state that Pasteurellosis in rabbits is common after shearing, when the animals are more exposed to the effect of cold.

Davis (1928) states that in New Zealand cases of pleurisy in sheep are ascribed to the effect of severe weather after shearing.

To the author's personal knowledge there is a belief among sheep farmers that clipping the wool from the perineal region in the earlier and thus colder months of the year predisposes ewes to mastitis.

Influence of Sunlight

Dodd (1916) describes cases of a dermatitis in herbivora in New South Wales affecting the unpigmented areas of the skin of animals being fed on an abundant growth of trefoil.

Theiler (1918) describes the disease known as geeldikkop, in which sheep feeding on the plant *Tribulus terrestris* during hot weather following rain become affected with a severe dermatitis of the exposed parts of the skin and with jaundice.

Quin (1933) emphasises the importance of sunlight in the etiology of geeldikkop and also states that cases of similar disease may occur in areas where *Tribulus* as an etiological factor can be ruled out, so that plants other than *Tribulus* can also have an etiological rôle.

Allen (1929, a), in the Punjab, met with cases of photosensitisation dermatitis of unpigmented areas of the skin of horses fed on large quantities of lucerne which was heavily infested with aphides.

Byrne (1940) in New South Wales found cases of dermatitis in white

pigs apparently associated with photosensitisation. These appeared in most aggravated form when the pigs were grazed on leguminous plants.

Bull and Macindoe (1926) review literature on photosensitisation dermatitis in animals feeding on buckwheat, clover, trefoil, St. John's wort and *Tribulus terrestris*.

Martnaglia (1932) describes a keratosis of non-pigmented areas of skin of cattle in South Africa resulting from exposure to sunlight.

Influence of Lack of Cleanliness of the Skin

Dunn (1850) records that, in stall-tied cattle, the hind feet are more frequently affected than the fore feet in cases of foot and mouth disease, and attributes this to the hind extremities being more exposed to wet and dirt.

Lawson (1870) considers that lack of grooming of the hind legs is one of the causes of grease in horses.

Simpson (1907) finds that neglect of grooming of the coat of dogs, with the resultant matting of hair, is a frequent source of irritation and consequent production of eczema in an eczematous subject.

Hutyra *et al.* (1938, Vol. III, p. 551) mention that the parts of the skin exposed to mechanical irritation from soiling with excreta are especially susceptible to potato dermatitis.

Influence of Pressure

Percival (1850) is of the opinion that laminitis is more frequent in the fore feet than in the hind owing to the greater proportion of the body weight which the former support and also because of the greater concussion the fore feet sustain in action; when horses are on board ship they are liable to laminitis due to the limbs having to act as props to maintain balance.

Greaves (1855) states that laminitis may occur after a severe run, after a hard day's work, after new shoeing or after standing idle in stall or loose-box.

Thomson (1900) finds that chronic laminitis is most commonly seen in fat horses or ponies that have little or nothing to do and have been put into too good a pasture or stood too long in one position, particularly on one leg when some injury has been done to the opposite limb.

Coe (1902) considers that rapid and continued work is liable to bring on an attack of laminitis in horses; also horses having to put extra weight on a sound foot to relieve an injured one occasionally suffer from laminitis in the previously sound foot.

Maitland (1928) showed that in guinea pigs experimentally infected with foot and mouth disease, if one hind foot were protected with cotton wool and bandage, vesicles did not form on the pad of that foot, whereas they formed as usual on the other foot. Conversely, she found that if inoculated guinea pigs were put into cages with wire bottoms with a mesh larger than the guinea pig's feet, vesicles formed on the toes and dorsal aspects of the

feet, sites never affected in other infected guinea pigs. This result was attributed to pressure being brought to bear on these parts through having to grasp the wire with the toes and through the feet slipping through the wire mesh. Pressure brought to bear on other parts of the body did not give satisfactory results. This work was suggested through observing that both pads and mouth parts are subjected to pressure much more than other parts of the body.

Influence of Dipping and Washing

Broad (1873) considers that washing of the legs of horses, especially with hot water, is a common cause of "mud fever."

Woods (1889) quotes work by Gervase Markham, who was of the opinion that a frequent factor in the genesis of laminitis is cold due to the sudden washing in the winter season of horses which are extremely fat and which are hot after working.

Montgomerie *et al.* (1938) incriminate washing and dipping as factors in the etiology of enzootic pneumonia in sheep.

Kehoe (1918) tells of two outbreaks of anthrax, one in cattle and the other in sheep, which occurred 24 to 48 hours after dipping. It was suspected that a latent infection had been present and the dipping possibly lowered the resistance.

Whitworth (1926) states that it has frequently been reported and observed that cattle and sheep die suddenly from anthrax after dipping, probably indicating breakdowns in carrier animals.

Bevan (1926) states that cattle suffering from mild or chronic trypanosomiasis, when exposed to heavy rains, may develop an acute attack of the disease and rapidly die. There are also indications from the field that if cattle be dipped in a solution too weak to be of therapeutic value, then the dipping may actually adversely affect the course of trypanosome disease in the same way as heavy rains.

Influence of Irritation from Parasites

Turner (1930) considers that the young stages of the liver fluke produce a nidus for the growth of *Cl. œdematiens,* thus leading to the onset of Black Disease (Infectious Necrotic Hepatitis of Sheep.)

Simpson (1907) believes that fleas in large numbers are an exciting cause of eczema in dogs with an eczematous tendency.

Kissileff (1938) has collected evidence which indicates that the dog flea is a causative agent in summer eczema in predisposed dogs.

Influence of Fatigue

Woodruff (1910) says that an important factor in the production of pneumonia in horses is overwork and fatigue, such as occurs in young horses

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newly brought into town or in seasoned horses at a very busy time. Besides overwork even a little extra exertion will often determine an attack of pneumonia in an animal not quite fit.

Influence of Psychic Factors

Hutyra *et al.* (1938, Vol. III, p. 443) mention fright, œstrum and milking as factors influencing the onset of cases of lactation tetany.

Williams (1909) met with a number of cases of illness in mares characterised by convulsions and spasms of the striated muscles. The affected animals were in all cases vigorous mares in high condition, of mature age but not old. They all had foals at foot and, in all or nearly all cases, had been having unrestricted freedom at pasture since foaling. When they were confined for a few hours the attack was ushered in without warning. He considered that the immediate cause of the attack was probably due to the sudden change of surroundings, a change from freedom to the stable or harness, probably by causing maternal anxiety for the foal. In the year 1889, when the unusually large number of seven cases occurred in rapid succession, favourable weather during the season had furnished luxuriant pasturage.

Harvey (1921) records cases of "equine tetanoid" as occurring in mares in association with such factors as œstrum, service, or excitement from removal of the foal.

Montgomerie *et al.* (1929) state that occasional cases of tetany occur in Welsh pony mares that have been removed from their foal and housed for as short a period as 12 hours.

Thiel and Boswell (1938) record a case of hysteria in a dog. Attacks occurred when the owner patted or talked to it or when the dog was taken out for exercise on the leash. The excitement aroused through being taken out appeared to be too great.

Influence of Defective Ventilation and Unhygienic Housing

Montgomerie *et al.* (1938) record that practically all of 50 sheep which had been housed in a stable overnight during a road journey showed symptoms of pneumonia and nine died. Another 50 sheep of the same lot, but which were not housed, remained healthy.

The harmful influence, on the incidence of disease in general and respiratory diseases in particular, of damp, draughty, poorly ventilated or badly drained animal houses is universally recognised.

Influence of General Environment

Simpson (1907) writes that it has been frequently brought to his notice that dogs subject to eczema have remained perfectly free from the disease so long as they are kept away from the Thames valley; but immediately on their return at any time of the year the disease will manifest itself. This was found to occur without change of diet and even in winter time.

Hewetson (1936) records a case of a dog suffering from attacks of hysteria which on being removed to Hewetson's kennels remained free from attacks during the seven weeks' stay, but on being returned home and put in its own pen fresh and repeated attacks ensued. On shifting the kennel to another part of the garden no further attacks occurred in over five years. A second dog kennelled in an outside water closet was affected with hysteria and on being removed to hospital the attacks ceased in 10 days and no further attacks occurred in the seven months' stay in the kennels, but on the first day the dog went home and was put in its own kennel she had an immediate attack. The dog was all right in owner's house but whenever it was shown that particular kennel an attack commenced.

Thiel and Boswell (1938) have had experience of cases of hysteria occurring in dogs which would appear to be in some manner associated with their home environment, as freedom from attack was obtained for weeks on end without any special treatment on removal to other kennels but with a renewal of the illnesses on return to their own homes.

Brownlee (1936) refers to literature illustrating that environmental factors appear to play a rôle in the development of both scrapie in sheep and paralysis in fowls in that "tainted" sheep or fowls may develop clinical manifestations of the respective disease on one farm while stock of similar breeding sent to another farm remain healthy ("the problem of the divided lot").

Elphick, C. (1926) is of the opinion that the surrounding conditions are of primary importance in the causation of summer mastitis in cattle. He believe that flies, heat, shade and water all go to bring about the condition.

Croudace (1926), Peel (1926), Doughty (1926), Elphick, H. S. (1926), Irvin (1926), all consider that the incidence of summer mastitis is reduced in cattle housed at night.

Thompson (1926) found in his experience that severe cases of summer mastitis occurred in the vicinity of trees and water. They were not common on top of the fells.

Pickering (1926) finds that cases of summer mastitis are more common during a change in weather conditions, e.g., a humid atmosphere with cold nights rather than during extremes of dryness or of moisture.

Anon (1928) finds that in a fine, dry summer fewer cases of summer mastitis are seen, but in a wet, "muggy," thundery, damp summer, such as 1927, a very large number of cases are met with.

Campbell (1928) found that in the summer of 1927, a cold, wet one, summer mastitis was prevalent and mortality heavy, whereas in the fine summer of 1928 the disease was less prevalent than for many years.

Similar Phenomena in the Human Subject

Kauntze (1926) records cases of cerebro-spinal meningitis occurring in

native porters sent to Nairobi from areas where this disease was endemic. They had been detained at Kisumu in segregation camps for three weeks to prevent carrying infection to their new quarters and while there only very seldom did a case of cerebro-spinal meningitis occur. They were then transported to Nairobi in wagons, 50 to a truck, and on arrival there after 24 hours in the train it was common to find two to three cases per truck, and during the first two days in Nairobi probably 10 per cent. of the batch went down with cerebro-spinal meningitis. He also says that somewhat similar instances could be quoted occurring during the pandemic of influenza in 1918.

Moore (1928) tells of the precipitation of fatal attacks of scarlet fever in two medical students who had been attending cases of scarlet fever and who remained free of symptoms of the disease until after playing very strenuous games.

Weiss (1932) records a case of urticaria solaris affecting the parts of the skin exposed to sunlight. It is a rare condition. Previously recorded cases are referred to.

Martin (1940) tells of a case of a woman who had suffered from asthma and was desensitised, apparently successfully, in that she remained well for 18 months. She was struck by an automobile and on regaining consciousness was in the midst of a severe attack of asthma. Another case was that of an elderly lady who had never had asthma until she fell down steps and lost consciousness. On regaining consciousness she was asthmatic and continued so until the time of her death.

An Editorial (1941) refers to the widespread dissemination of the virus of poliomyelitis when contrasted with the relatively limited incidence of the disease, thus suggesting the existence of contributing factors. Reference is made to a number of recorded reports of cases of poliomyelitis occurring after a surgical operation, after accidents and after strenuous exercise. "Sabin found that the interval between this exercise and the onset of paralysis is usually less than 24 hours. This short interval, Sabin believes, suggests not only that these persons were already harbouring the virus in their nervous system but also that it might already have involved their medulla and spinal cord, and that the exercise could be the factor which converts what might have remained an unapparent or nonparalytic type of poliomyelitis into the frankly paralytic type of the disease."

Similar Phenomena in Experimental Animals

Charrin and Roger (1890) found that six white rats subjected to fatigue all died within 50 hours after inoculation with anthrax virus, whereas five controls inoculated with the same dose and allowed to rest survived.

Bullock and Cramer (1919) found that exposure to cold and wet rendered mice less resistant than the unexposed controls to the action of *Cl. welchii* culture or toxin given parenterally.

Boycott and Price-Jones (1926) found that rats, exposed to fatigue after being infected *per os* with Gaertner's bacillus, more readily succumbed than did rats allowed to rest.

Bevan (1926) found that, in small-scale experiments with guinea pigs inoculated with a strain of Trypanosoma brucei, immersion in cold water at three-day intervals appeared to hasten the course of the disease.

In an Editorial (*loc. cit.*) reference is made to work by Sabin, who found that " rhesus monkeys inoculated with the human virus may develop a non-paralytic or even inapparent form of poliomyelitis with typical neuronal and infiltrative lesions in the spinal cord. He further found that the virus may actually reach the lower motor areas without paralysis necessarily ensuing, provided the proper equilibrium between the host and the virus exists or is achieved before too many cells are affected." Work by Levinson is also referred to. He demonstrated " that monkeys immersed in cold water and compelled to swim to the point of exhaustion developed more severe paralysis than did either those which remained in their cages or those which were immersed in water at body temperature and protected from exercise and chilling."

Discussion

Anatomical studies on the effect of some environmental factors on the animal body have been made and recorded. Hill and Muecke (1913) found that in the human subject, when living in a warm, confined atmosphere, the nose and throat flush and swell, becoming turgid with tissue lymph and covered with a thick secretion.

Seyle (1937) states that a syndrome appears when a severe injury is inflicted upon the organism. " This syndrome is independent of the nature of the damaging agent and represents rather a response to damage as such. Exposure to cold, traumatic injuries, excessive muscular exercise, spinal shock, acute infections and intoxications with various drugs will evoke this syndrome if they damage the organism sufficiently. The course of this reaction which we have interpreted as an expression of general defence may be divided into three stages. During the first or acute stage, observed in the rat ordinarily six to forty-eight hours after the initial injury, one notes rapid decrease in the size of the thymus, spleen, lymph glands and liver; disappearance of fat tissue; œdema formation, especially in thymus and loose retroperitoneal connective tissue; accumulation of pleural and peritoneal transudate; loss of muscular tone; fall of body temperature; formation of acute erosions in the digestive tract, particularly in the stomach, small intestine and appendix; loss of cortical lipoids and chromaffin substance from the adrenals; and sometimes hyperæmia of the skin, exophthalmos, increased lacrymation and salivation. In very severe cases focal necrosis of the liver and dense clouding of the crystalline lens may be observed." In a few days a certain resistance is built

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up so that the same stimulus does not have so much effect. If the stimulus is kept on, however, ultimately a stage of exhaustion follows. The three stages are: (i) stage of alarm; (ii) stage of resistance; (iii) stage of exhaustion.

Whether the above changes play any part in the production of the diseases mentioned in this paper is not known.

Animals in general avoid exposing themselves to those potentially harmful environmental factors. Healthy animals spend much time in grooming themselves to remove dirt from the skin; many instinctively take care to avoid soiling the skin with urine or fæces. Sheep in particular have a desire to avoid bright sunlight and the sheep also is very averse to walking through mud or water. Animals also try to avoid cold winds and rain, and the desire of cats to avoid wetting the skin is proverbial.

Although a number of diseases, both infectious and non-infectious, appear under certain circumstances to be precipitated by certain environmental factors, these factors alone are not sufficient to produce any of these diseases. Animals are often exposed to the influence of cold, dampness, transport, exercise, sunlight, dirt, pressure, etc., without anything more than a purely physiological response resulting. However, the same animals exposed to such influences at other periods of their lives may suffer severe injury. There must, therefore, be other factors in operation when these pathological reactions occur. In the case of the infectious diseases it is evident that the specific micro-organism is one of the other factors. Moreover, it is well established that many specific organisms may at times be present in the animal tissues without setting up any very obvious disease, indicating that factors other than the causal organism are necessary for the production of frank cases.

It would appear probable that, since it has been indicated in this paper that both the infectious and the non-infectious diseases can be precipitated by similar environmental factors, an agent, corresponding to the specific organism of the infectious diseases, also comes into operation in these non-infectious diseases. Since specific micro-organisms act as foreign protein in the tissues, other kinds of foreign protein may also be involved in disease production. That food and other proteins may be absorbed in their native condition has been shown in the human subject and in experimental animals. Brownlee (1940) reviews this subject and shows that many of the non-infectious diseases of the domestic animals occur under circumstances which probably favour the absorption of native-food and other proteins. In some of the diseases dealt with in the present paper there is also some circumstantial evidence that native food protein may have been absorbed, e.g., Williams (under section "Influence of Psychic Factors") and Blumer *et al.* (under section "Influence of Transport and Travelling") found cases of the respective diseases to occur after grazing on luxuriant pasture. However, that foreign protein is an actual

etiological factor concerned in these non-infectious diseases has not yet been proved.

It will be obvious that many of the outbreaks of disease dealt with in this paper are exceptional in the conditions of their occurrence and that the majority of cases of these diseases occur with no very obvious change in the environment to account for their onset. Also, present environment and the presence of foreign protein are not the only factors concerned, as, in a number of individuals exposed apparently to the same environment and the same foreign protein, some may show frank symptoms and others only occult. However, a closer study of present and past environments and genetic constitution of individuals may shed further light on these problems.

Summary

Under certain conditions exercise; transport and travelling; frights, accidents and operations; cold and wet; loss of protective coverings; sunlight; lack of cleanliness of the skin; pressure; dipping and washing; irritation from parasites; fatigue; psychic factors; defective ventilation and unhygienic housing; general environment; appear to influence the onset of certain diseases. These conditions and the nature of the action of these factors are discussed.

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SIDEBONES

By H. LOMAS

It would be best to preface any remarks on this interesting subject by saying that it is not intended to be comprehensive but only to cover points met with in practice and any available post-mortems.

Further, it was the writer's duty to examine for soundness and certify that horses bought were sound for a large commercial company. This meant that one was acquainted with the animals from the beginning to the end of their working lives in this ownership.

It should be noted that, as a four-year-old would only be accepted if of very great merit and that a seven-year-old would be rarer still, the writer has no experience of the affection in horses younger than four; and also that even a partially-formed one would be sufficient to cause rejection at any age.

The reason for this was the liability to lameness in having to work at trotting pace.

Under these working conditions it was found that lameness could and did arise from a partially-formed sidebone, whilst the superior edge of the lateral cartilage was quite flexible on pressure.

Lameness.—The carman will report that the horse goes a little lame after stopping during the delivery of goods, the lameness being slight but noticeable, and passes off after going a few hundred yards. As time goes on the period of lameness lengthens until it becomes chronic and the horse has to be relegated to work at walking pace.

Post-mortem.—In a large stud it is not very difficult to obtain a foot with a fully-developed sidebone and, having seen it after boiling, the memory of the picture remains—an ugly-looking, rough mass of calcified tissue, almost indescribable. It is, however, a very different and difficult proposition, and the opportunity seldom comes, for one to get the chance of a post-mortem on the partially-developed sidebone. It means that one has to wait until such a horse has the misfortune to die or has to be destroyed for some other reason.

No opportunity was ever missed of a post-mortem on one of these cases, yet there were very few in my forty years of practice.

In these it is not advisable to boil the parts. The skin is removed and the wall of the foot below the cartilage is stripped. The procedure now is to take thin shaves with a good, sharp scalpel. This method—it is the surface, not the edge, that is shaved—showed that the scalpel met small, isolated objects of resistance to the knife—little islands of calcification having a different colour than cartilage, and somewhat resembling that of bone. These areas varied in size and were always more prevalent near the bone, becoming smaller and progressively fewer as one approached the superior border of the cartilage, the latter sometimes being entirely free.

It would seem that these findings coincide with what one meets in practice. It suggests that calcification from below upwards is the route of the progress of the disease.

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News

VETERINARY LABORATORY, WEYBRIDGE*

DR. W. HORNER ANDREWS vacated the post of director of the Veterinary Laboratory, Ministry of Agriculture, Weybridge, at the end of September, having held the appointment since 1927. He has taken up an appointment in the office of the Animal Health Branch, Ministry of Agriculture. Prior to taking over the Weybridge post, Dr. Andrews held research appointments in South Africa, where he served on the staff of the late Sir Arnold Theiler. He went to South Africa in 1909 and shared in the research work which led to the development of the Onderstepoort Laboratory near Pretoria which is now so well known. During 1914-18 he joined the South African Army Veterinary Corps and saw service in German South-West Africa, but was recalled to civil duty in 1915. In Africa he had wide experience of virus diseases of animals, Protozoan infections, livestock poisoning and poisonous snakes, and contributed to the literature on these subjects. When a veterinary degree was established in South Africa Dr. Andrews was appointed professor of physiology, and for some years after his return to Great Britain he was an examiner in physiology for the Royal College of Veterinary Surgeons. He was thus able to bring wide experience when he took over the Weybridge Laboratory. In the nature of that appointment much time was devoted to committee work and questions of policy, and much of the development of veterinary research in Great Britain during recent years has been influenced by work done on such committees. Dr. Andrews' personal attention was perhaps directed largely to research on foot-and-mouth disease, consideration of problems relating to bovine contagious abortion, the organisation of a growing department dealing with poultry disease and a host of other questions. The good wishes of his friends go with him in his new field of work.

PROF. T. DALLING is retiring from the chair of animal pathology in the University of Cambridge at the end of this year to assume the directorship of the Ministry of Agriculture's Veterinary Laboratory at Weybridge. He graduated at the Royal (Dick) Veterinary College, Edinburgh, in 1914, and served throughout the War of 1914-18 with the Royal Army Veterinary Corps. Later he joined the late Prof. S. H. Gaiger at Glasgow, and together they worked on some important sheep diseases. Dalling was conspicuously successful in dealing with lamb dysentery, and within a few years, in the course

* Reprinted from *Nature*, London.

of which he joined the staff of the Wellcome Physiological Research Laboratories at Beckenham, he had discovered the cause and devised a means for its prevention which has resulted in the annual saving of enormous numbers of lambs. This led him and his colleagues to some valuable comparative studies on the transference of maternal immunity to the offspring in different animal species.

At Beckenham Prof. Dalling interested himself with other problems and was one of a team which recognised that a form of infectious jaundice in dogs is caused by the same spirochæte as Weil's disease in man. He was also largely responsible for overcoming the difficulties involved in the preparation and distribution on a large scale of the prophylactics used in the Laidlaw-Dunkin method of immunising dogs against distemper. He also worked on fowl pox, fowl paralysis, bacillary white diarrhœa and other diseases of poultry. Recently, in collaboration with the late A. Stanley Griffith, he obtained evidence to suggest that the vole type of acid-fast organism discovered by A. Q. Wells may prove of value as an immunising agent against tuberculosis in cattle.

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Errata.—In the article " Chemical Changes Occurring During Growth of Acid-fast Bacteria in Synthetic Media," by A. Eden and H. H. Green, in our October number, Vol. 97, No. 10, the lettering of Figs. I, II and III was unfortunately omitted. The three figures are therefore reproduced on this loose leaf for insertion at page 320 of the original article.

There is also one error in Table I of the article, where the figure 0.20 for the dextrose value of Strain C on the 10th day should read 0.84.

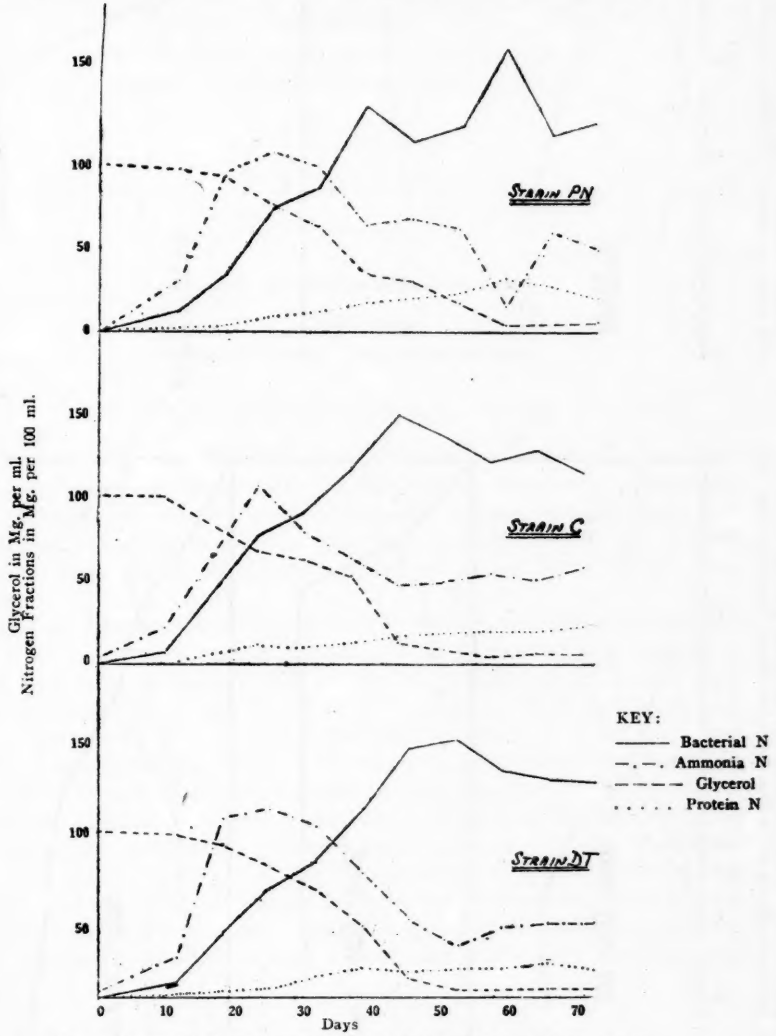

FIG. I.—Chemical changes occurring during the growth of three strains of human type tubercle bacillus on B.A.I. synthetic medium.

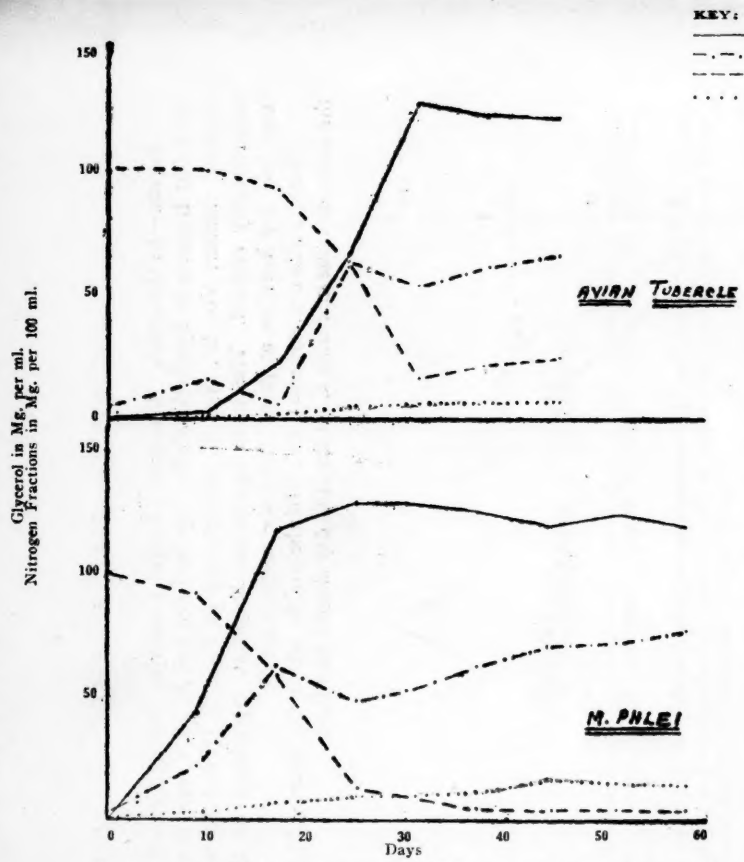

FIG. II.—Chemical changes occurring during the growth of Avian type tubercle bacillus and Timothy bacillus on B.A.I. synthetic medium.

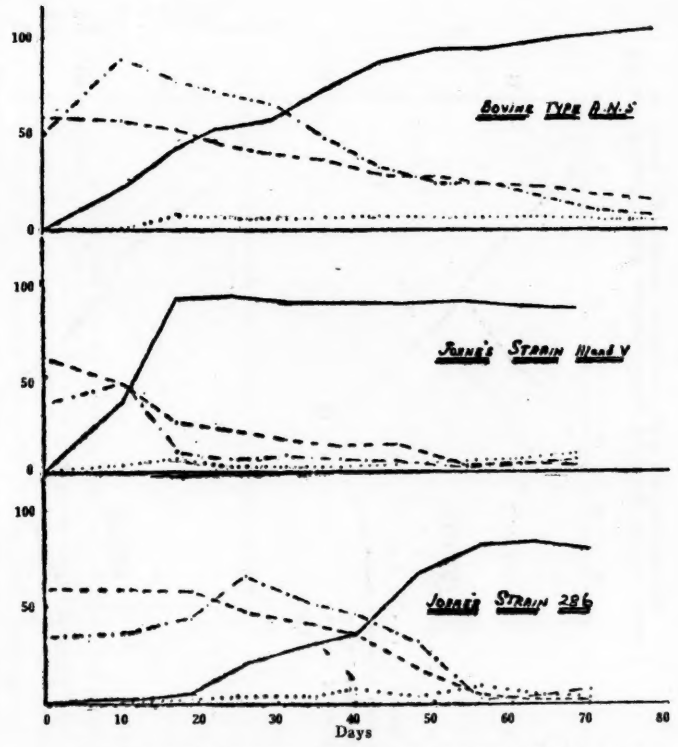

FIG. III.—Chemical changes occurring during the growth of bovine type tubercle bacillus and two strains of Johnes' bacillus on Watson and Reid's synthetic medium.